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The Investigation of the Effects of Loading Rate and Stress Concentration Factors on the Notch Properties of Three Sheet Alloys at Subzero Temperatures

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FOREWORD

This report was prepared by the Applied Mechanics Section, Metals and Ceramics Laboratory, Directorate of Materials and Processes, Deputy for Technology, Aeronautical Systems Division. The program was conducted under Project No. 7351, "Metallic Materials," Task No. 735106, "Behavior of Metals" as an internal effort. This work was performed by Mr. A.W. Brisbane during the period from July 1960 to February 1962.

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ABSTRACT

The effect of theoretical stress concentration factors, and loading rates at 26°, -78°, and -196°C are presented for 301XH stainless steel, Rene 41, and Vasco Jet-1000 sheet materials.

The unnotched specimens, tested at room temperature, were not appreciably affected by loading rate; however, some effects were observed for the specimens tested at subzero temperatures. The loading rate had some effect on the notched tensile specimens at all test temperatures. The temperature effect was more pronounced on the notched tensile specimen at the fastest loading rate.

In most instances the tensile strength increased as the temperature decreased. The percent elongation for the three materials was highest at the -78°C test temperature. Type H-11 material became very brittle at -196°C and shattered upon fracture.

The notch to unnotch strength ratio decreased as the stress concentration factor increased. The 301XH stainless steel was the least notch sensitive.

The amount of martensite transformed in the notched 301XH stainless steel specimens varied with the notch geometry and loading rate, with the exception of the notched specimen with a stress concentration factor of 12.8 at -196°C.

This technical documentary report has been reviewed and is approved.

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INTRODUCTION

Using metals at cryogenic temperatures is a problem of great concern, especially since the advent of the missile and space vehicle era. Embrittlement of metals has been found to be enhanced by the presence of stress concentrations. Some known factors which determine the degree of embrittlement of metals are stress concentrations, sub-zero temperatures, strain rates, and size effects, (ref 1).

Since the rise of interest in cryogenics, many investigators have become involved in studying the effects of stress concentrations, section size, strain rate, and other parameters at sub-zero temperatures, (refs 2,3,4,5,6).

This investigation was undertaken to determine what the effects on the mechanical properties of an austenitic stainless steel, H-11 steel, and a nickel base alloy would be by varying the stress concentration factors and the loading rate. The tests were conducted at room temperature, -78°C, and -196°C. The K_t factors of 1.74, 2.95, 6.0, and 12.8 were selected for this investigation to cover both the mild and sharp notch regions.

MATERIALS

The materials used in this investigation were 0.062-inch thick sheet 301XH stainless steel secured from the Republic Steel Co., 0.062-inch thick sheet René -41 alloy secured from the Haynes-Stellite Co., and 0.066-inch thick sheet Vasco Jet-1000 steel secured from the Vanadium Alloys Steel Co. The chemical composition of these materials are given in table 1.

TABLE 1

Chemical Composition of Alloys (Weight Percent)

	C	Mn	Si	S	P	Cr	Ni	Mo	V	Co	Fe	Al	Ti	B
301XH	0.12	1.12	0.32	0.017	0.02	17.33	7.44	-	-	-	-	-	-	-
Rene-41	0.12	-	0.14	-	-	19.10	53.04	10.01	-	11.62	.75	1.75	3.00	0.006
Vasco Jet-1000	0.35	0.29	0.77	0.011	0.015	4.88	-	1.18	0.47	-	-	-	-	-

HEAT TREATMENT

The 301XH stainless steel was tested in the as rolled condition. The René-41 and Vasco Jet-1000 materials were heat treated as given in table 2.

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TABLE 2

Heat Treatment Schedule

René-41

1975°F - 30 minutes, air cool

1400°F - 16 hours, air cool

Vasco Jet-1000

Preheat 1450°F - 20 minutes, air cool

1850°F - 30 minutes, air cool

Triple temper at 1100°F - 1+1+1 hour

SPECIMENS

Unnotched and notched tensile specimens were made in accordance with figure 1. The notched specimens have varying notch radii of 0.002, 0.010, 0.050, and 0.195 inch. These notch radii correspond to stress concentration factors of 12.8, 6.0, 2.95, and 1.74 respectively, computed according to Peterson (ref 7).

TESTING CONDITIONS

The specimens were pin loaded through holes to minimize the eccentricity of load application. The specimens were tested at 26°, -78°, and -196°C. The -78°C temperature was obtained with a mixture of dry ice and acetone. The -196°C temperature was obtained by using liquid nitrogen.

All of the low temperature test specimens were immersed in the coolant during testing. Both the notched and unnotched specimens were tested at crosshead loading rates of 0.005, 0.050, 1.0, and 8 inches per minute.

EQUIPMENT

All of the tests were conducted on a 50,000 pound capacity Baldwin Emery SR-4 testing machine. The load-strain curves were autographically recorded except for the 8 inches/minute loading rate. To record the maximum load of specimens at 8 inches/minute loading rate, a calibrated dynamometer was used in conjunction with a recording oscillograph shown in figure 2. The tensile cryostat is shown in figure 3. This cryostat was designed by Battelle Memorial Institute (ref 8).

RESULTS

The tensile strength, 0.2 percent offset yield strength, and percent elongation in a two-inch gage length of 301XH as rolled stainless steel, René-41 alloy, and Vasco Jet-1000 are presented as a function of temperature and loading rate. Also presented are the notch strengths as a function of stress concentration, loading rate, and temperature. The notch to unnotch strength ratio is presented as a function of temperature and stress concentration factor (K_t). The data for each test condition is an average of three specimens.

The results of the 301XH stainless steel are presented in figures 4 through 11. The results of the René-41 nickel base alloy are presented in figures 12 through 16. The results of the Vasco Jet-1000 alloy are presented in figures 17 through 22.

The tabular results of the 301XH stainless steel, René 41 alloy, and the Vasco Jet-1000 alloy are given in tables 3, 4, and 5, respectively.

DISCUSSION OF RESULTS

The 301XH stainless steel is one of the face centered cubic metals which has been frequently investigated in the past few years to determine its behavior at sub-zero temperatures.

It has been observed that the tensile and yield strengths of metals generally increase when tested at sub-zero temperatures. This is true until the test temperature is decreased to a point where the material becomes brittle, which may be considered the ductile-brittle transition temperature. The unnotch strength of the 301XH stainless steel was observed to increase as the temperature decreased, except for the loading rate of 8 inches/minute at -196°C. In this case the strength was observed to decrease, as shown in figure 4.

Srawley and Beachem (ref 9) found that the loading rate did not have an appreciable effect on the net fracture stress and the cracked specimen strength ratio of a 422M martensitic stainless steel. Their data revealed that ultimate strength increased as the loading rate increased.

The yield strength was observed to increase only slightly as the temperature decreased, and also, there was an increase in the yield strength of the 301XH stainless steel as the loading rate increased. The yield strength for the 1 inch/minute loading rate is shown in figure 4.

It was observed from the load-strain curves of the 301XH stainless steel that a load drop occurred in the plastic region at the sub-zero temperature. In figure 5 it is observed that the discontinuous extension or load drop occurs at higher values of plastic strain with increasing test temperature. This is in agreement with the findings of Powell et al (ref 10), who observed a discontinuous extension of 301 stainless steel at small values of elastic strain when tested at -263°C. It is well known, that the martensitic transformation in the 301 stainless steel is enhanced by an applied stress at sub-zero temperatures and a local temperature rise in the metal is less likely to occur at higher temperatures. This observed behavior would be expected whether the discontinuous extension is due solely to the martensitic transformation or is due to a local temperature rise resulting from local slip accompanied by martensite formation. Powell et al (ref 10) found that the martensite transformation in 301 stainless steel is strain rate dependent and gave the following explanation for the drop in load. At some point in the test specimen, the discrete nature of slip accompanied by martensite formation, coupled with a very low specific heat, results in a temperature rise. The flow stress is time and temperature dependent and the load carrying ability decreased with localized deformation. The effect is transient as the elastic strain energy is dissipated in localized plastic deformation; during the drop in load the temperature gradient disappears and the resultant stress becomes less than the flow stress. The load must now build up until the next instability sets in.

The percent elongation of the 301XH stainless steel increased between room temperature and -78°C and then decreased at -196°C for all loading rates. In figure 4 one can see

that loading rate has little effect on the elongation. The highest percent elongation in the 301XH stainless steel occurred at the -78°C test temperature. In examining the unnotched specimens after fracture it was observed that the transformed area covered the entire 2-inch gage length at -78° and -196°C. The transformed area of the unnotched specimens was restricted to the region adjacent to the fractured surface for specimens tested at 26°C.

The effects of K_t and loading rate on the 301XH stainless steel at room temperature, -78°, and -196°C are shown in figure 4. It was observed that there was little difference in the notch strengths for the various K_t factors at room temperature, for a given loading rate. At a K_t of 12.8 the notch strength is the same at -196°C for both loading rates 0.005 and 8 inch/minute. This is also true for K_t of 6 under the same conditions. Here it appears that as the notch becomes very sharp the 301XH material is insensitive to loading rate. The influence of the loading rate on the notch strength of the 301XH material is illustrated in figure 6. There is essentially no effect of loading rate except at the fastest loading where the notch strength is observed to decrease, with the greatest decrease occurring at room temperature. It is observed in figure 6, that the loading rate does not have any effect at -196°C for a K_t of 12.8 and only a slight effect at the -196°C temperature for K_t of 6. This is attributed to temperature and notch sharpness. Here the notch is very sharp and at a very low temperature which greatly inhibits yielding at the notch. Fractures of the 301XH stainless steel for K_t of 12.8 at room temperature, -78°, and -196°C are illustrated in figure 7. The influence of loading rate on the notch to unnotch strength ratio of 301XH stainless steel is illustrated in figure 8. At the loading rate of 0.005 inch/minute the notch to unnotch strength ratio (NSR) decreases with test temperature. The largest variation in NSR is observed to occur at the loading rate of 8 inches/minute at -78°C. There is no difference in the notch to unnotch strength ratio at the 8 inches/minute loading rate for the -196°C and at room temperature. In figure 9 it is shown that there is very little decrease in the notch to unnotch strength ratio with increasing notch sharpness for the fast loading rate. However, for the slowest loading rate there is a decrease in the notch to unnotch strength ratio with increasing notch sharpness at the lower test temperatures. It was observed that with the same notch geometry the size of the transformed area increased with decreasing loading rate; this is shown in figure 10. The effect of strain rate on the martensite transformation in 301 stainless steel was found to depend upon the magnitude of the strain rate, (ref 10). Less transformation has been observed to accompany higher strain rate, an effect attributed to the temperature rise in increasing rapid deformation at very low temperatures. Hardness tests were taken in the transformed area of the unnotched specimen. Shown in figure 11 is a plot of Rockwell "C" hardness versus temperature for the 301XH stainless steel. The hardness of the 301XH stainless steel increased ten points between room temperature and -196°C tests.

The unnotch tensile properties of the René-41 alloy is shown in figure 12. The loading rate did not have an appreciable influence on the ultimate yield strength and percent elongation. The data plotted in figure 12 is for the loading rate of 1 inch/minute. The ultimate strength and yield strength of the René-41 alloy increased slightly with decreasing test temperature. The percent elongation increased slightly between room temperature and -78°C, and then decreased at -196°C. There was no necking in any of the notched or unnotched René-41 specimens for any of the three test temperatures. The brittle type fracture surfaces were normal to the tensile axis. This is illustrated in figure 13.

The effects of K_t and loading rate on the Rene-41 alloy at room temperature, -78°, and -196°C are shown in figure 12. It was observed that there was little difference in the

notch strength when varying the loading rate and holding the K_t factor constant except for K_t of 12.8 at 8 inches/minute loading rate. Here the notch strength was much lower. Shown in figure 14 is the notch strength versus the loading rate for the René-41 alloy. It was observed that the loading rate did not have any effect on the René-41 specimen with K_t of 1.74 and 2.95. There was no effect for all K_t factors at the first three loading rates 0.005, 0.050, and 1 inch/minute. The loading rate did have some effect at 8 inches/minute for K_t factors of 6.0 and 12.8. The notch to unnotch strength ratio versus temperature is illustrated in figure 15. The notch to unnotch strength ratio is about unity for K_t of 1.74 and 2.95 for all rates of loading and all test temperatures. At a K_t of 6.0 and 12.8 the notch to unnotch strength ratio of the René-41 alloy is less than unity. The notch to unnotch strength ratio of René-41 with K_t of 6 and 12.8 is approximately the same except at a loading rate of 8 inches/minute. This behavior is due to the sharp notch and little plastic flow at the notch. All notched René-41 specimens had a brittle type fracture appearance, as did the unnotched specimens. In figure 16, it is shown that for a K_t greater than 2.95 the notch to unnotch strength ratio decreases below unity and this decrease is greatest for the fastest loading rate.

The tensile, yield strength, and percent elongation of the Vasco Jet-1000 material versus temperature is shown in figure 17. The influence of loading rate on the properties of the Vasco Jet-1000 alloy is seen to have the greatest effect at the 8 inches/minute loading rate.

At room temperature and -78°C the influence of loading rate on the ultimate strength of the Vasco Jet-1000 alloy is only slight. At approximately-100°C there is a crossover between the ultimate strength at loading rates of 0.005, 0.05, 1.0, and 8 inches/minute. At 100°C the Vasco Jet-1000 alloy tends to become loading rate sensitive. Only the 0.005 inch/minute loading rate shows no effect. This material became very brittle at the -196°C test temperature and it was not feasible to record the load-strain curves. Fractures of the Vasco Jet-1000 steel for K_t of 12.8 at room temperature -78° and -196°C are illustrated in figure 18. The percent elongation could not be measured at the -196°C temperature at loading rates of 0.050, 1.0, and 8 inches/minute. This was because at these loading rates when the specimen fractured they shattered into several pieces.

The notch strength versus temperature for the Vasco Jet-1000 alloy is shown in figure 19. The influence of temperature was greatest in the sharp notched specimen at both slow and fast loading rates. The sudden drop in notch strength has been termed the notch strength transition temperature (ref 11). Shown in figure 20, the greatest influence of loading rate was observed at -78°C for a K_t of 12.8. In figure 21 is the notch to unnotch strength ratio versus test temperature using K_t as the parameter. In checking the notch to unnotch strength ratio data of Vasco Jet-1000 alloy obtained in this investigation it was found that for similar K_t factors the notch to unnotch ratios were much lower than those found in references 12 and 13. This difference is possible due to the strength level to which the Vasco Jet-1000 alloy was heat treated. The influence of loading rate did not have any apparent effect on the mild (K_t = 1.74) notched specimen except at a loading rate of 8 inches/minute at -196°C. The notch to unnotched strength ratio of the Vasco Jet-1000 alloy decreases sharply at K_t of 12.8, as the temperature decreased at loading rates of 1 and 8 inches/minute. The influence of temperature and loading rate on the notch to unnotch strength ratio versus K_t is shown in figure 22. At room temperature there is no appreciable effect of loading rate on the notch to unnotch strength ratio. The loading rate does have some influence on the notch to unnotch strength ratio of the Vasco Jet-1000 alloy at -196°C. Here the ratio is higher for the 8 inches/minute loading rate, wherefore at room and -78°C temperatures the notch to unnotch strength ratio is higher at the 0.005 inch/minute loading rate.

SUMMARY AND CONCLUSIONS

The notch tensile strength versus the test temperature of the 301XH, René-41, and Vasco Jet-1000 materials are presented in figure 23. These data are for loading rates of 0.005 and 8.0 inches/minute at K_t of 12.8. The notch strength of the Vasco Jet-1000 alloy was affected most by the loading rate. The loading rate of 8 inches/minute lowered the notch strength of the 301XH and René-41 materials but did not change the shape of the curves. At -196°C the notch strength of the 301XH stainless steel was the same for 0.005 and 8 inches/minute loading rates. The notch to unnotch strength ratio versus K_t for the 301XH, René-41, and Vasco Jet-1000 materials are presented in figure 24. At K_t of 6 the René-41 alloy exhibited the lowest notch to unnotch strength ratios at a loading rate of 8 inches/minute for all temperatures tested. The very low notch to unnotch strength ratio of the Vasco Jet-1000 material at K_t of 12.8 can be attributed to the embrittlement at -196°C.

The 301XH as rolled stainless steel exhibited a dependence of stress and temperature for phase transformation. It was also observed that the loading rate had some effect on the martensite transformation.

The loading rate had a pronounced effect on the martensite transformation in the notched 301 stainless steel specimens. This was shown by the transformed area at the notch, (figure 10). The hardness test on the 301XH stainless steel indicated that the amount of martensite increased as the test temperature decreased.

The loading rate did not have any appreciable effect on the ultimate, yield strength, and percent elongation of the René-41 alloy. The notched René-41 specimens were affected by the 8 inches/minute loading rate. The notch to unnotch strength ratio of the René-41 alloy was less than unity for K_t greater than 2.95 at all test temperatures.

The notch strength of 301XH stainless steel, René-41, and Vasco Jet-1000 versus test temperature is shown in figure 25. Curves are plotted for K_t 6.0 and 12.8 K_t at a constant loading rate. The strength of the 301, René-41, and Vasco Jet-1000 materials are affected by notch sharpness and temperature. The notch sharpness decreases the notch strength for the three materials but the shape of the curves for the 301XH stainless steel and René-41 are the same at 6.0 and 12.8 K_t. The stress versus temperature curve of Vasco Jet-1000 material at a K_t of 12.8 changes drastically from the stress versus temperature curve for 6.0 K_t.

It is concluded that even though the 8 inches/minute loading rate is not considered a very fast loading rate it will give some indication of how these materials behave when the K_t is varied and tested at low temperatures. It was found that the loading rate did not change appreciably the shape of stress versus temperature curve for the face centered cubic metals but the body centered cubic metal was affected to a large degree.

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TABLE 3

TENSILE PROPERTIES OF 301XH STAINLESS STEEL

TEST TEMP °C	LOADING RATE IN./MIN	YIELD STRENGTH PSI	ULTIMATE STRENGTH PSI	ELONG. PERCENT IN 2"	NOTCH TENSILE STRENGTH				NOTCH/UNNOTCH STRENGTH RATIO			
					K_t=12.8	K_t=6.0	K_t=2.95	K_t=1.74	K_t=12.8	K_t=6.0	K_t=2.95	K_t=1.74
R.T.*	0.005	180,900	201,900	10.0	214,800	220,800	222,300	220,700	1.06	1.09	1.10	1.09
R.T.	0.050	184,400	201,700	10.0	221,900	219,000	220,000	220,000	1.10	1.08	1.09	1.09
R.T.	1.0	194,500	202,100	7.3	220,800	220,700	215,000	218,400	1.09	1.09	1.06	1.08
R.T.	8.0		203,800	6.3	175,900	184,200	183,200	182,300	0.86	0.90	0.90	0.89
-78	0.005	188,500	247,400	28.7	219,900	227,600	243,300	262,300	0.89	0.92	0.98	1.06
-78	0.050	188,700	244,200	26.7	226,000	228,600	247,000	258,400	0.92	0.93	1.01	1.06
-78	1.0	202,100	242,000	27.7	226,900	234,400	247,200	249,400	0.93	0.97	1.02	1.03
-78	8.0		240,000	29.3	192,700	213,500	221,900	238,900	0.80	0.89	0.92	1.00
-196	0.005	200,900	320,200	25.0	237,500	259,700	311,700	321,000	0.72	0.78	0.94	1.00
-196	0.050	203,700	327,500	25.5	237,500	263,000	296,100	342,000	0.72	0.80	0.90	1.04
-196	1.0	227,400	327,100	25.0	237,500	270,800	302,100	328,900	0.72	0.83	0.92	1.00
-196	8.0		244,000	22.0	237,000	263,200	259,900	263,200	0.97	1.08	1.07	1.08

* ROOM TEMPERATURE

TABLE 4

TENSILE PROPERTIES OF RENÉ-41 ALLOY

TEST TEMP °C	LOADING RATE IN./MIN	YIELD STRENGTH PSI	ULTIMATE STRENGTH PSI	ELONG. PERCENT IN 2"	NOTCH TENSILE STRENGTH				NOTCH/UNNOTCH STRENGTH RATIO			
					K_t=12.8	K_t=6.0	K_t=2.95	K_t=1.74	K_t=12.8	K_t=6.0	K_t=2.95	K_t=1.74
R.T	0.005	157,100	200,000	12.0	164,300	182,000	199,200	209,200	0.82	0.91	0.99	1.04
R.T.	0.050	157,900	195,400	11.0	167,900	188,600	197,800	210,400	0.86	0.96	1.01	1.07
R.T.	1.0	163,800	197,800	12.0	173,200	187,300	205,100	209,400	0.87	0.94	1.03	1.06
R.T.	8.0		198,500	12.0	131,900	144,000	170,300	212,100	0.66	0.72	0.86	1.06
-78	0.005	167,200	216,700	13.5	174,900	194,000	211,300	222,700	0.80	0.89	0.97	1.05
-78	0.050	165,900	215,500	13.5	177,900	194,700	210,400	222,200	0.82	0.90	0.97	1.03
-78	1.0	173,000	217,500	13.7	178,100	196,500	214,900	226,300	0.82	0.90	0.99	1.04
-78	8.0		210,000	14.7	134,800	141,100	205,800	221,300	0.64	0.67	0.98	1.05
-196	0.005	181,900	221,900	7.0	169,000	204,000	226,300	235,600	0.76	0.91	1.02	1.06
-196	0.050	183,300	224,200	7.0	177,200	204,900	225,400	242,200	0.79	0.91	1.00	1.08
-196	1.0	193,300	221,600	7.0	177,300	203,000	226,800	241,300	0.80	0.91	1.02	1.09
-196	8.0		220,400	6.6	126,700	147,400	225,000	225,900	0.57	0.67	1.02	1.02

TABLE 5

TENSILE PROPERTIES OF VASCO JET-1000 STEEL

TEST TEMP °C	LOADING RATE IN./MIN	YIELD STRENGTH PSI	ULTIMATE STRENGTH PSI	ELONG. PERCENT IN 2"	NOTCH TENSILE STRENGTH				NOTCH/UNNOTCH STRENGTH RATIO			
					K_t = 12.8	K_t = 6.0	K_t = 2.95	K_t = 1.74	K_t = 12.8	K_t = 6.0	K_t = 2.95	K_t = 1.74
R.T.	0.005	174,100	204,600	10.0	251,200	248,000	263,400	252,000	1.2	1.2	1.28	1.23
R.T.	0.050	178,600	204,100	9.3	243,100	251,200	261,000	252,800	1.19	1.23	1.27	1.23
R.T.	1.0	189,100	205,000	9.0	245,500	252,000	255,300	255,300	1.19	1.22	1.25	1.24
R.T.	8.0		218,800	9.0	252,000	253,600	258,500	249,600	1.15	1.16	1.18	1.14
-78	0.005	184,900	216,600	11.3	247,500	277,200	275,200	266,300	1.14	1.28	1.27	1.22
-78	0.050	194,700	219,000	10.0	251,200	269,900	278,500	269,500	1.14	1.25	1.27	1.23
-78	1.0	195,400	217,800	10.0	172,000	273,200	278,000	269,500	0.78	1.25	1.27	1.23
-78	8.0		223,600	10.0	134,200	271,500	275,500	268,700	0.60	1.21	1.23	1.20
-196	0.005	230,500	260,300	6.0	66,900	248,800	300,000	305,300	0.25	0.95	1.15	1.17
-196	0.050		229,400		71,900	210,900	309,700	278,300	0.31	0.91	1.35	1.21
-196	1.0		217,600		79,000	218,300	290,200	280,500	0.36	1.00	1.33	1.28
-196	8.0		176,500		67,100	219,500	236,600	268,000	0.38	1.24	1.34	1.52

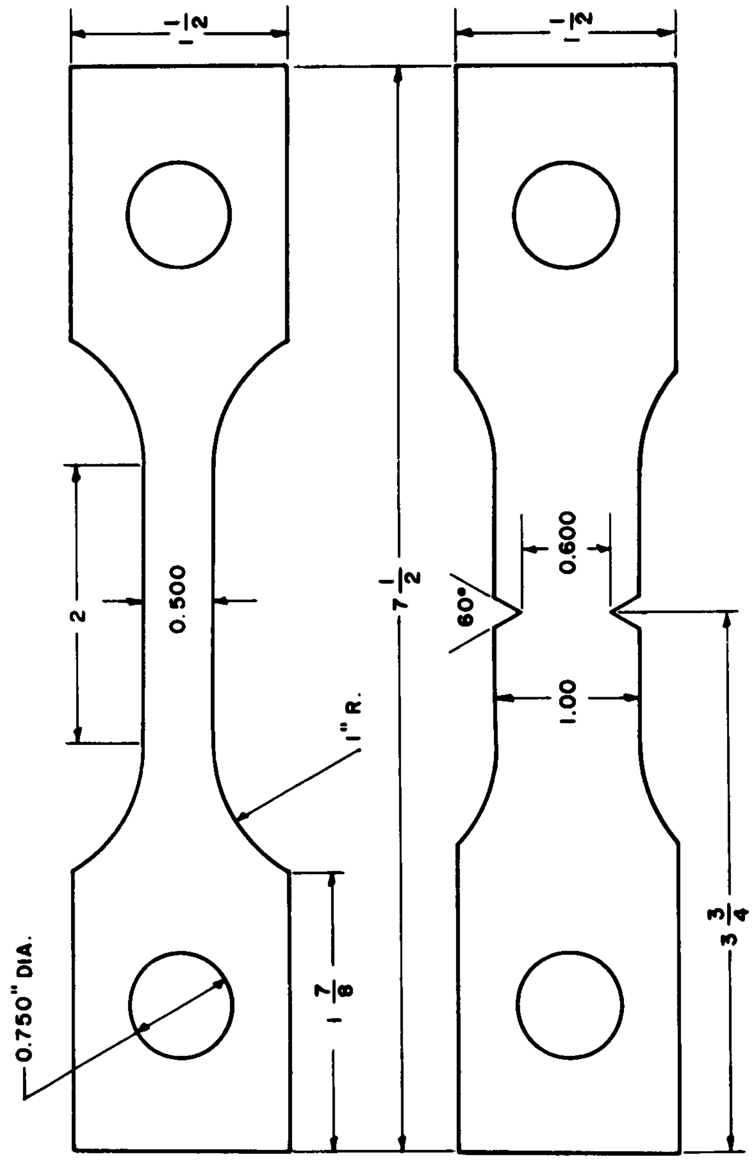


Figure 1. Unnotched and Notched Tensile Specimen.

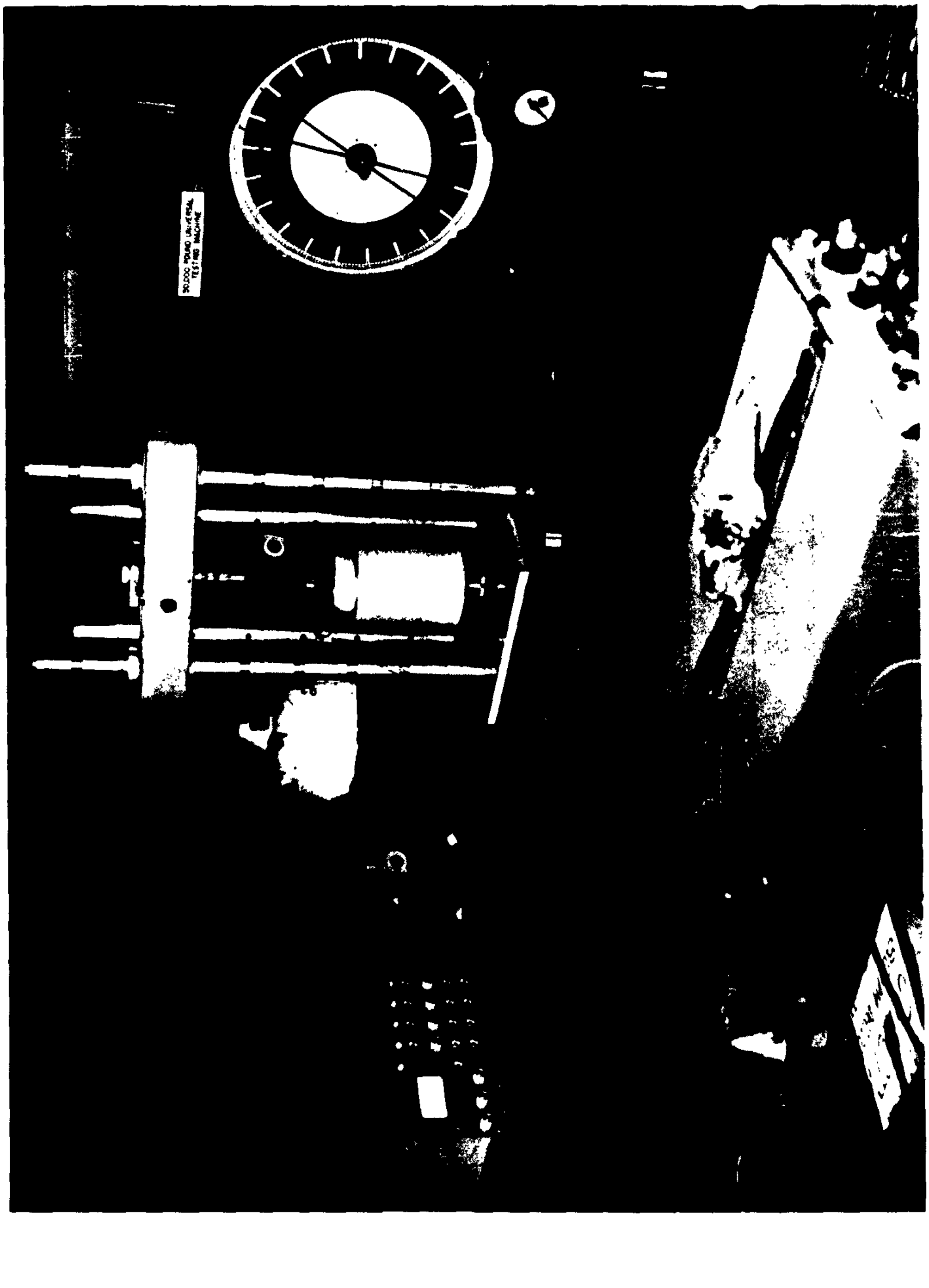


Figure 2. Test Setup for Testing at Loading Rate of 8 inches/minute (a) Dynamometer (b) Recording Oscillograph.

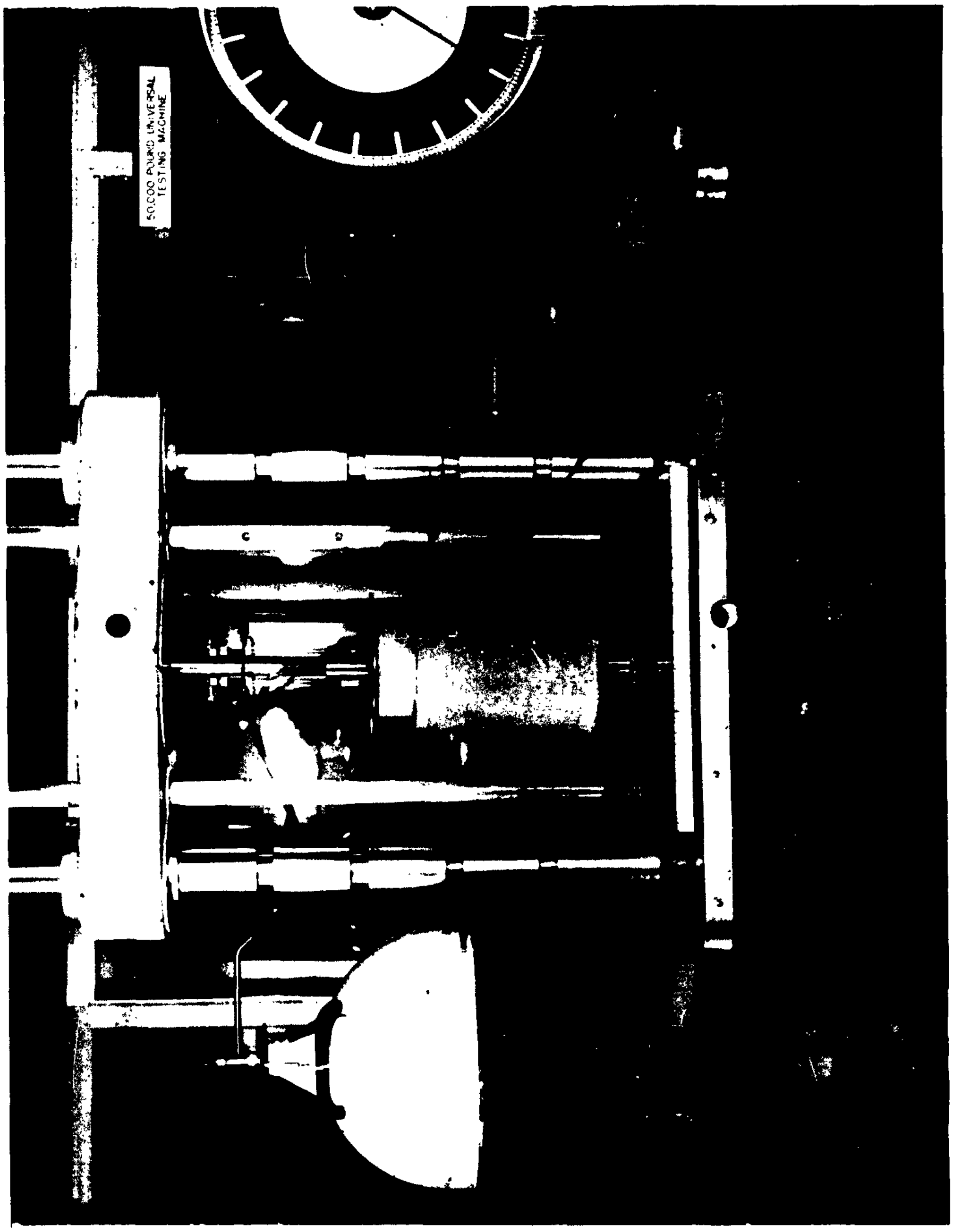


Figure 3. Setup for Cryogenic Testing Showing Extensometer (a)

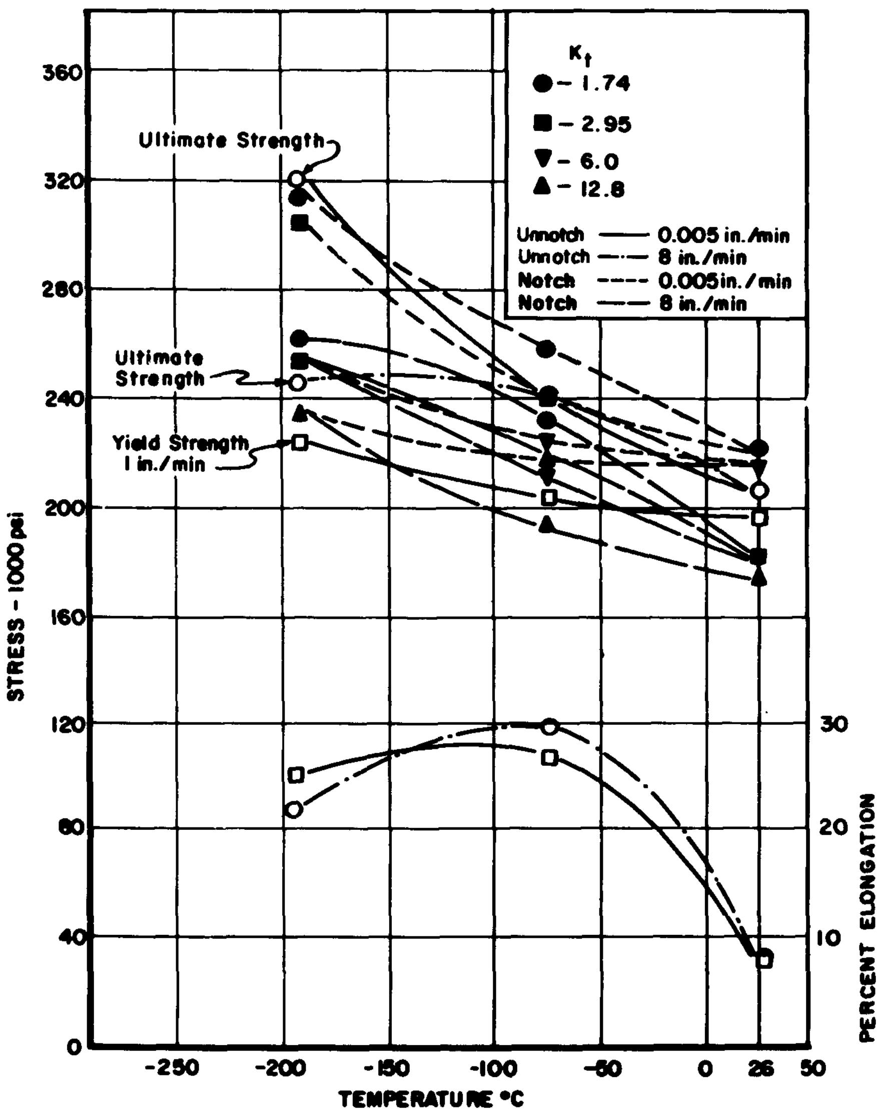


Figure 4. Yield Ultimate and Notch Tensile Strength and Percent Elongation versus Temperature for 301XH Stainless Steel at Loading Rates of 0.005 and 8 inches/minute K_t of Notched Specimen are 1.74, 2.95, 6.0, and 12.8.

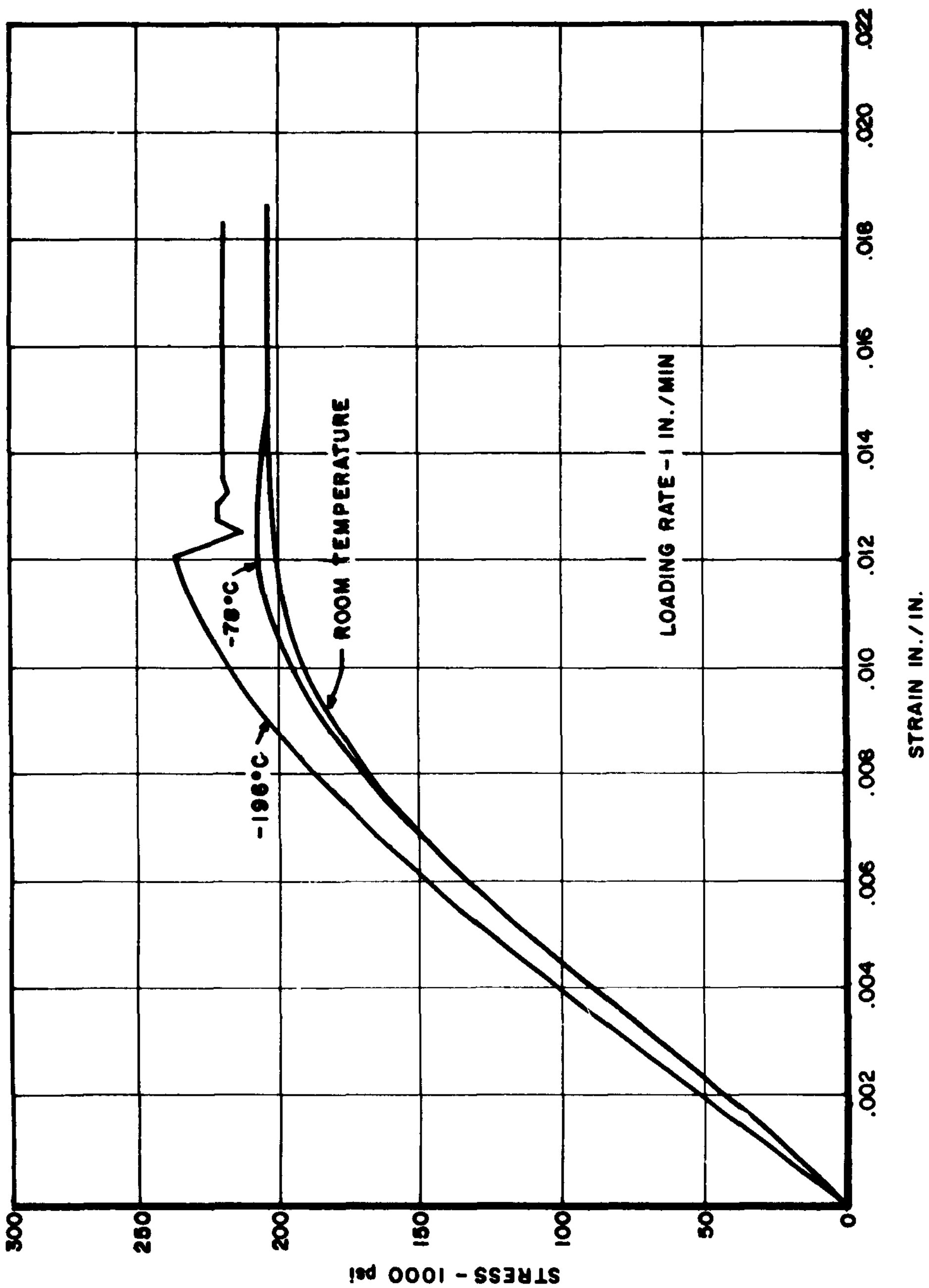


Figure 5. Stress versus Strain Curve for 301XH Stainless Steel at Room Temperature, -78°, and -196°C. Loading Rate is 1 inch/minute.

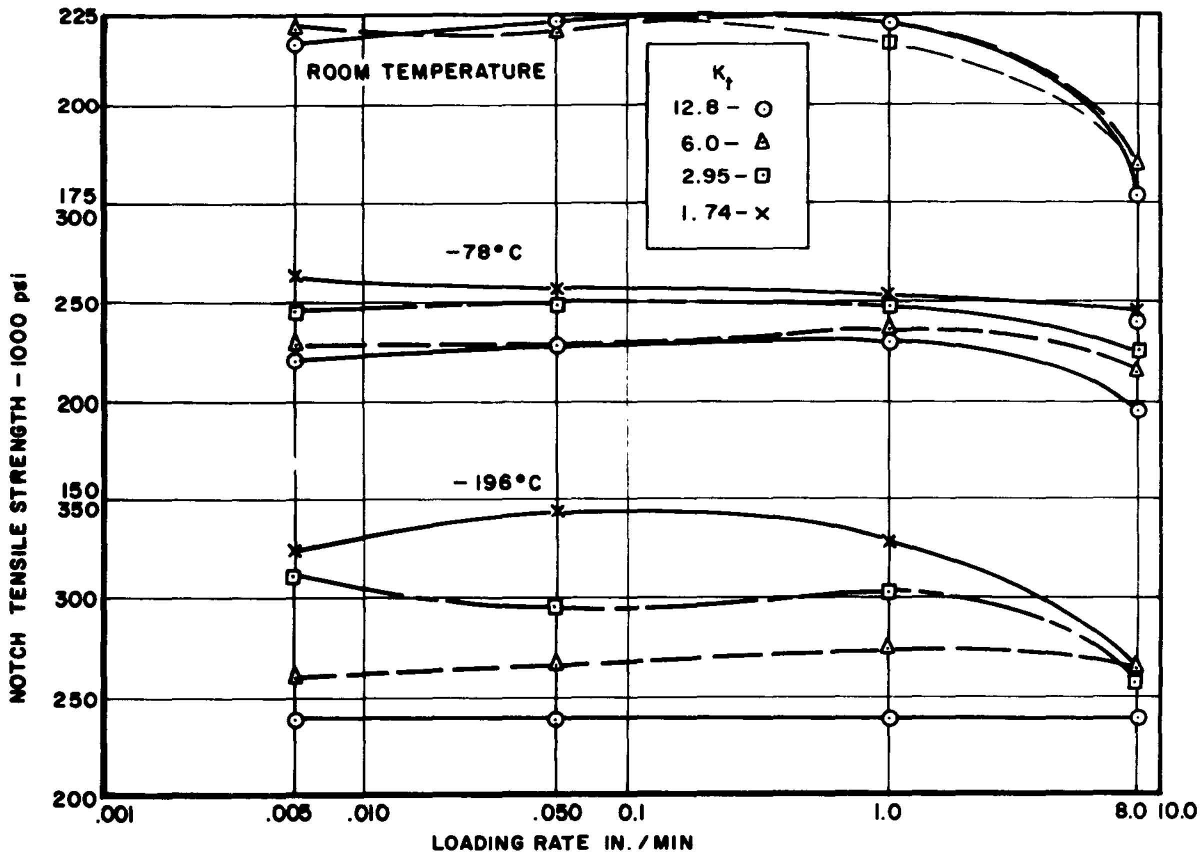


Figure 6. Notch Strength versus Loading Rate for 301XH Stainless Steel at Room Temperature, -78°, and -196°C, for K_t of 1.74, 2.95, 6.0, and 12.8.

ROOM TEMPERATURE

- 78°C

- 196 °C

Figure 7. Fracture of Notched 301XH Stainless Steel for Various Test Temperatures, A K_t Factor of 12. 8, and A Loading Rate of 1 inch/minute.

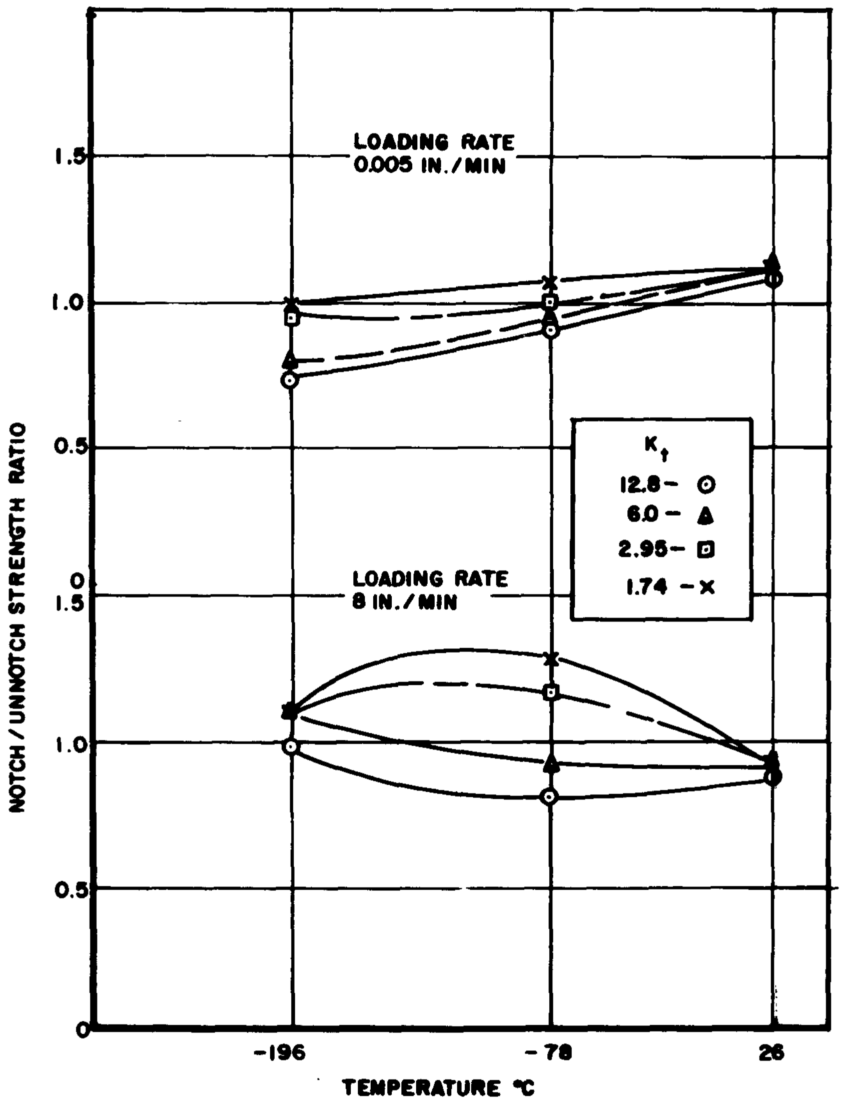


Figure 8. Notch to Unnotch Strength Ratio versus Temperature for 301XH Stainless Steel at Loading Rates of 0.005 and 8 inches/minute and K_t of 1.74, 2.95, 6.0, and 12.8.

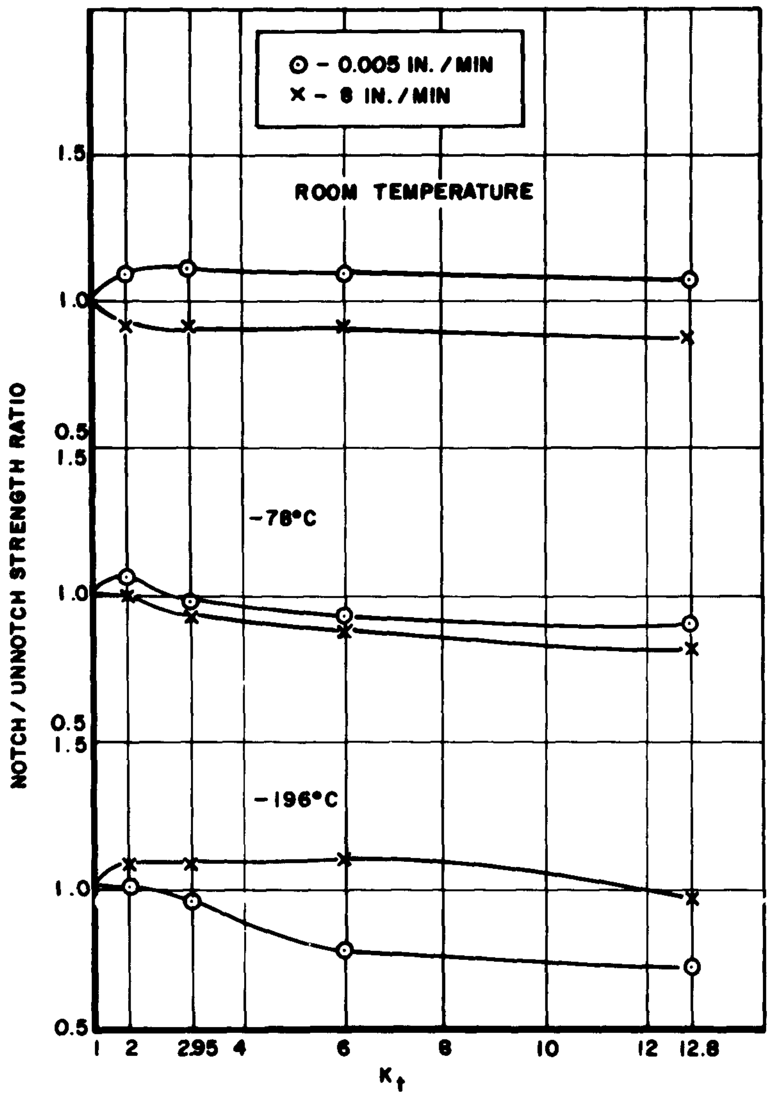


Figure 9. Notch to Unnotch Strength Ratio versus K_t for 301XH Stainless Steel at Room Temperature. -78° and -196°C for Loading Rates of 0.005 and 8 inches/minute.

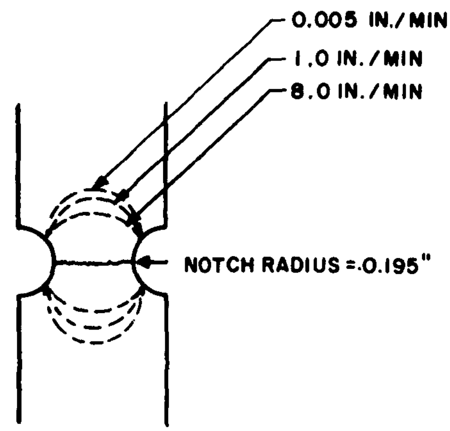


Figure 10. Transformed Area of 301XH Stainless Steel at -78°C with a Notch Radius of 0.195 in. and at Loading Rates of 0.005, 1.0, and 8 inches/minute.

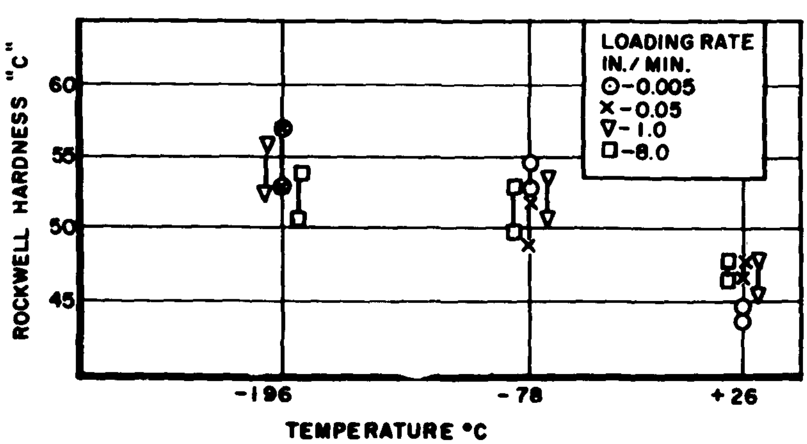


Figure 11. Rockwell "C" Hardness of 301XH Stainless Steel in the Transformed Area.

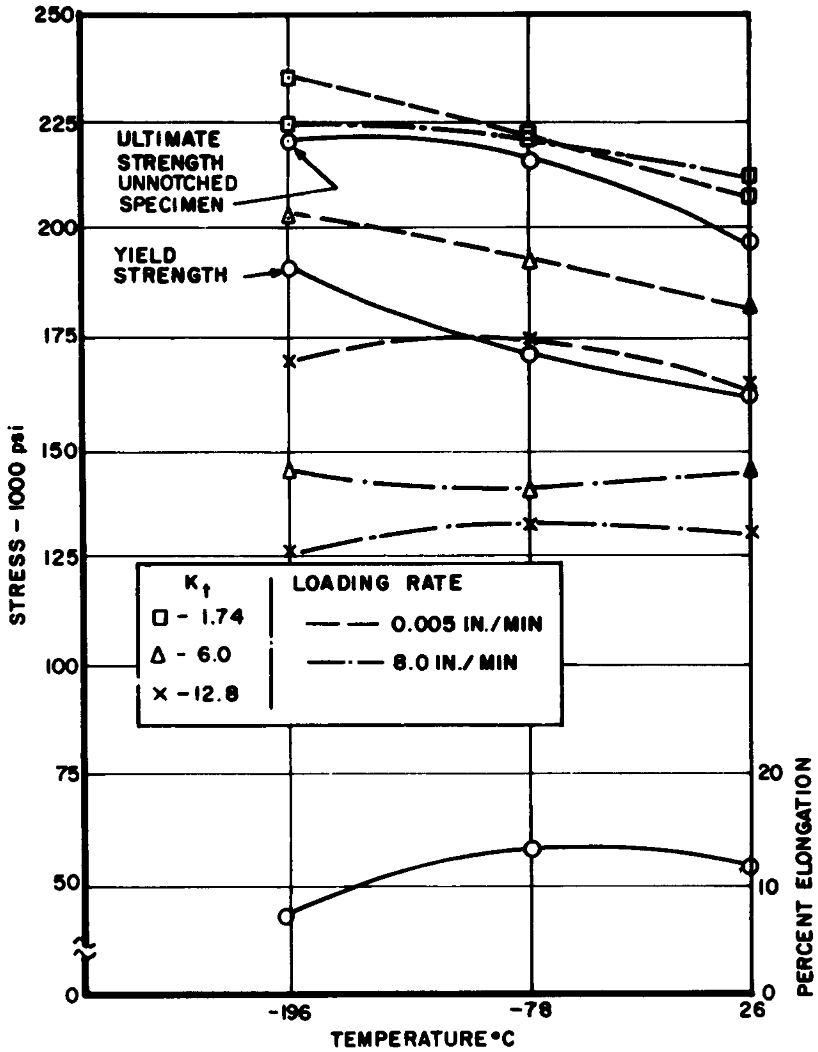
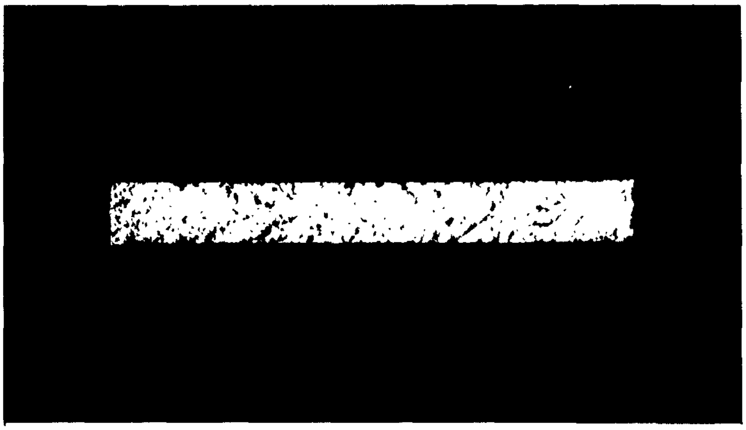


Figure 12. Yield, Ultimate, and Notch Tensile Strength and Percent Elongation versus Temperature for René-41 for Loading Rates of 0.005 and 8 inches/minute and Notched Specimens having K_t of 1.74, 6.0, and 12.8.



UNNOTCHED (-196°C)

ROOM TEMPERATURE
K_t = 6.0

-78°C, K_t = 6.0

Figure 13. Fracture of Unnotched and Notched René-41 Tensile Specimen.

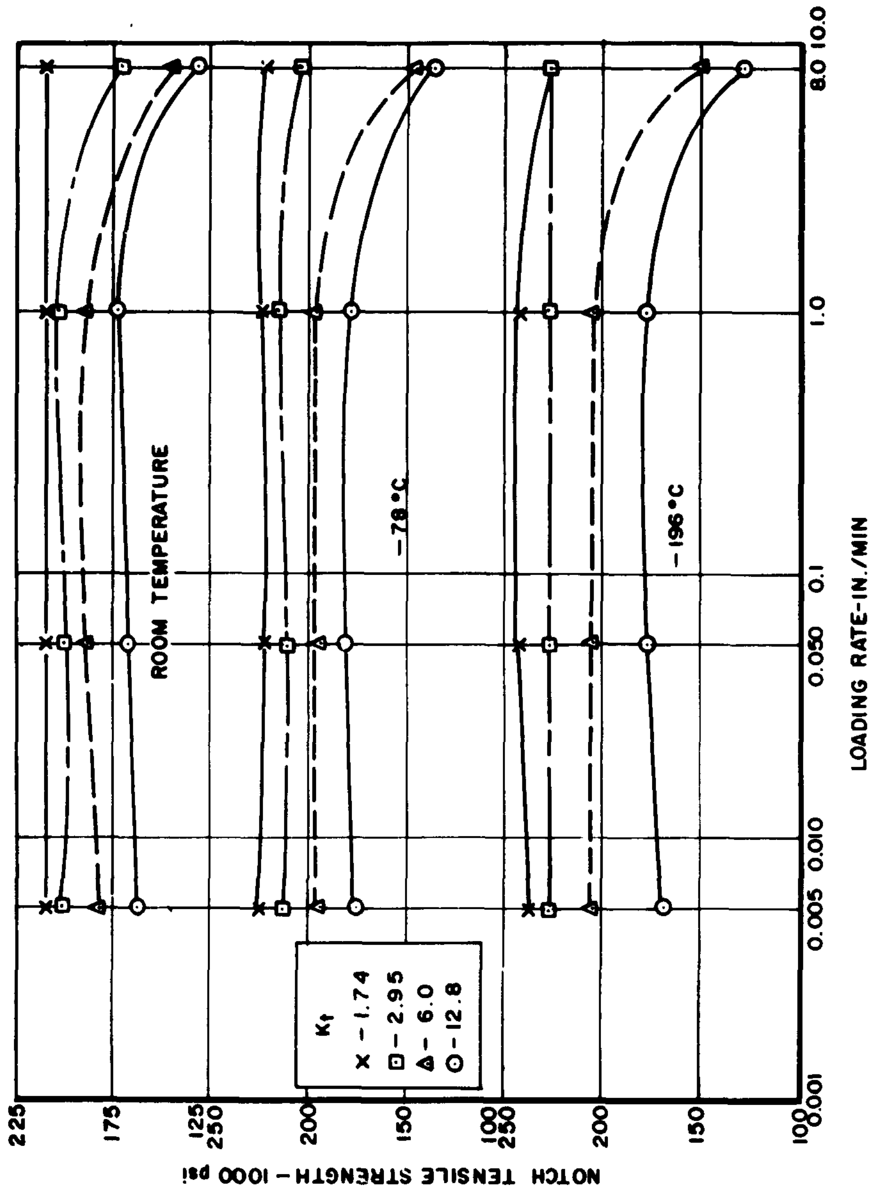


Figure 14. Notch Tensile Strength versus Loading Rate for René-41 with K_t of 1.74, 2.95, 6.0, and 12.8 at Room Temperature, -78° and -196°C.

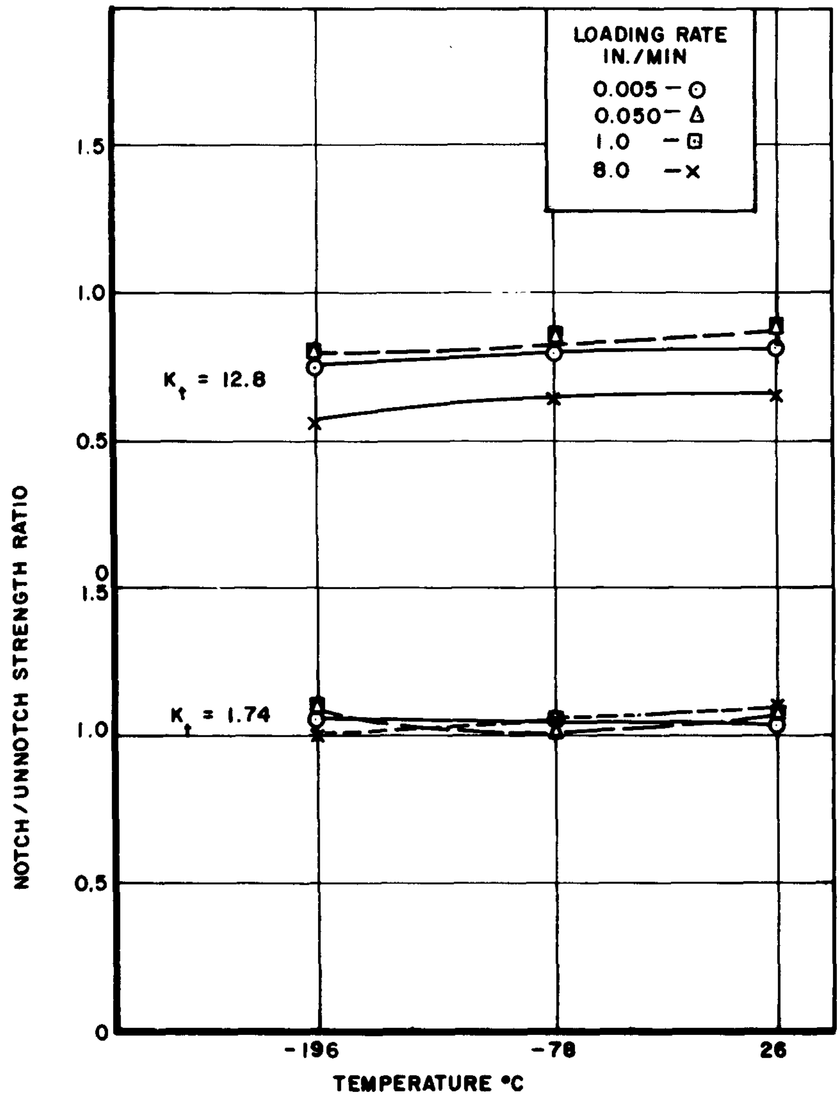


Figure 15. Notch to Unnotch Strength Ratio versus Temperature for René-41 at Loading Rates of 0.005, 0.050, 1.0, and 8 inches/minute for K_t of 1.74 and 12.8.

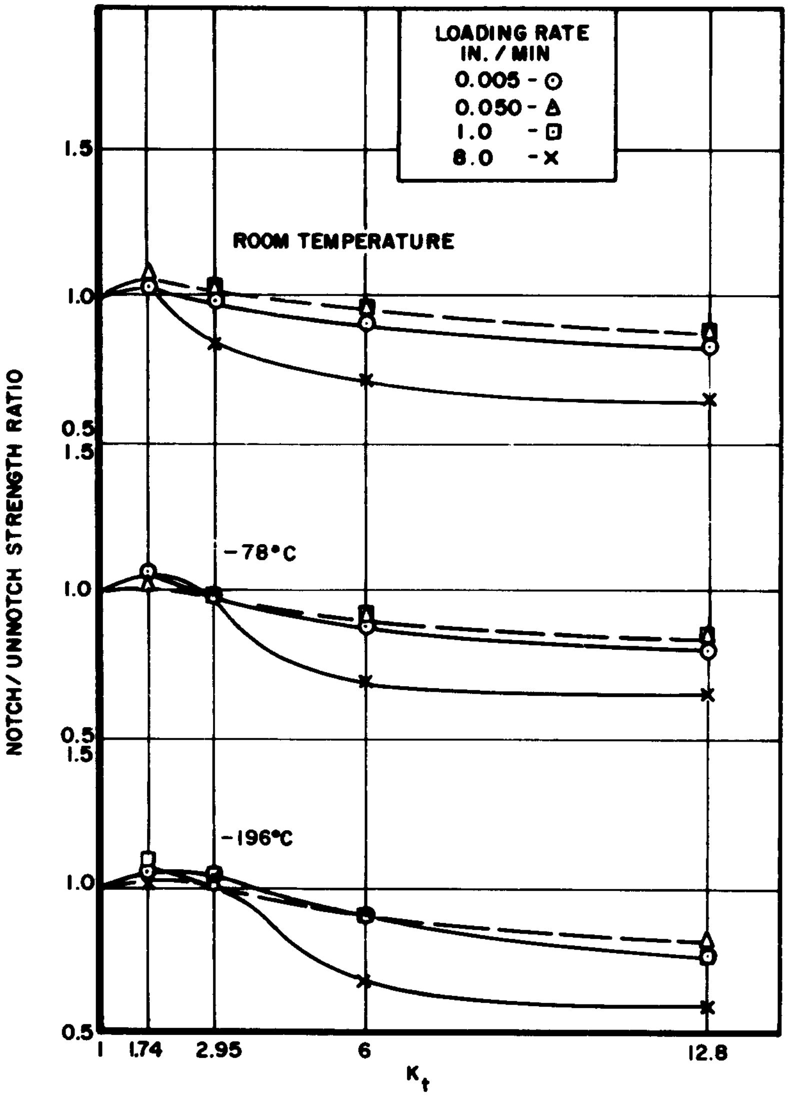


Figure 16. Notch to Unnotch Strength Ratio versus K_t for René-41 at Loading Rates of 0.005, 0.050, 1.0, and 8 inches/minute and Tested at Room Temperature, -78°, and -196°C.

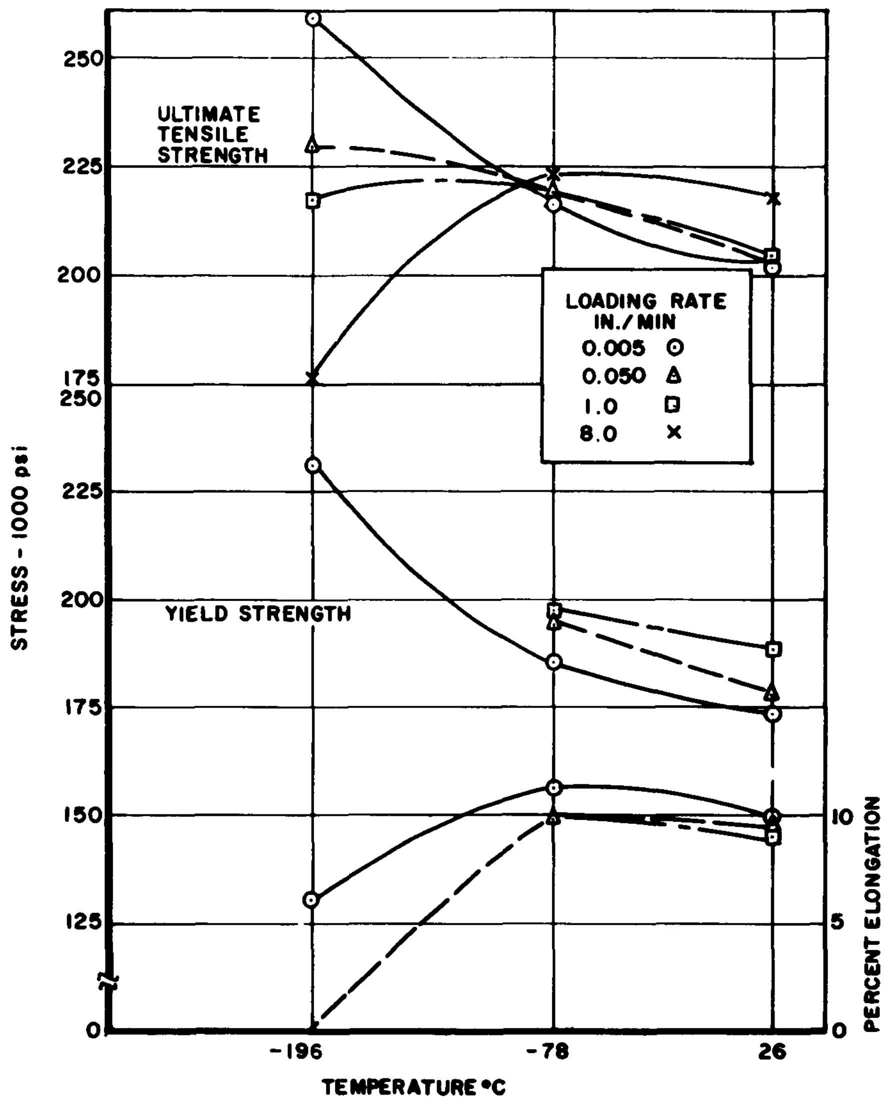
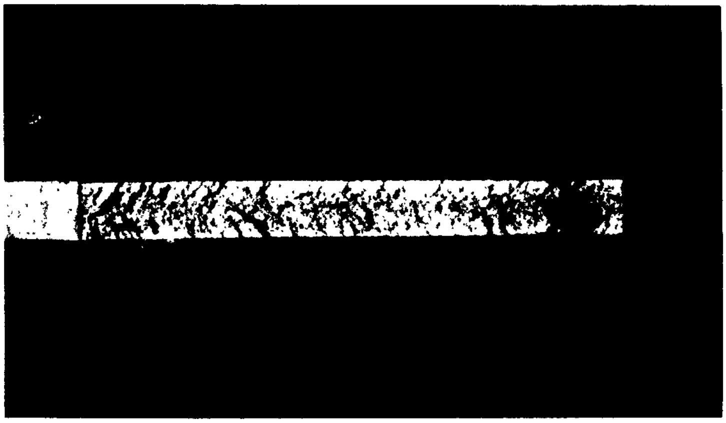


Figure 17. Yield and Ultimate Tensile Strength and Percent Elongation versus Temperature for Vasco Jet-1000 at Various Loading Rates.

ROOM TEMPERATURE

−78 °C



−196 °C

Figure 18. Fractures of Notched Vasco Jet-1000 Specimens for Various Test Temperatures, a K_t of 12.8 and a Loading Rate of 1 inch/minute.

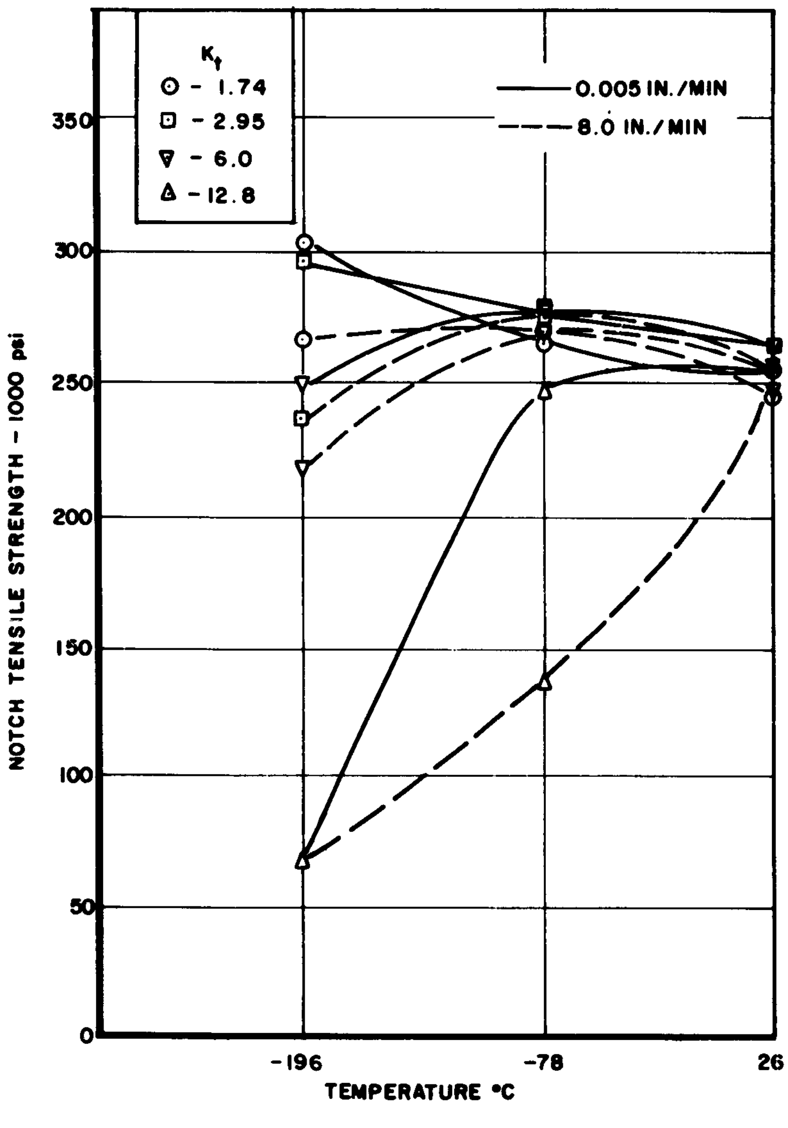


Figure 19. Notch Tensile Strength versus Temperature for Vasco Jet-1000 Alloy at Loading Rates of 0.005 and 8 inches/minute with K_t of 1.74, 2.95, 6.0, and 12.8.

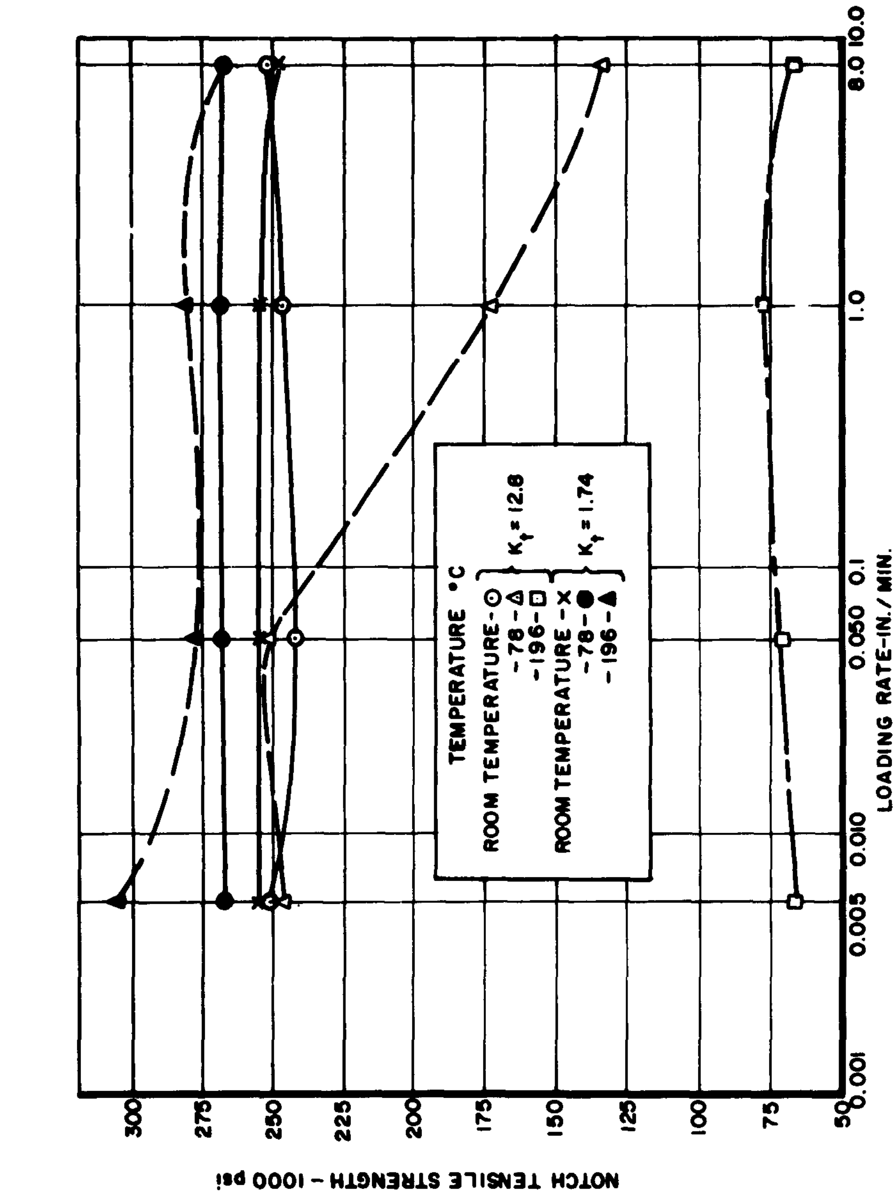


Figure 20. Notch Tensile Strength versus Loading Rate for Vasco Jet-1000 at Room Temperature, -78°, and -196°C with K_t of 1.74 and 12.8.

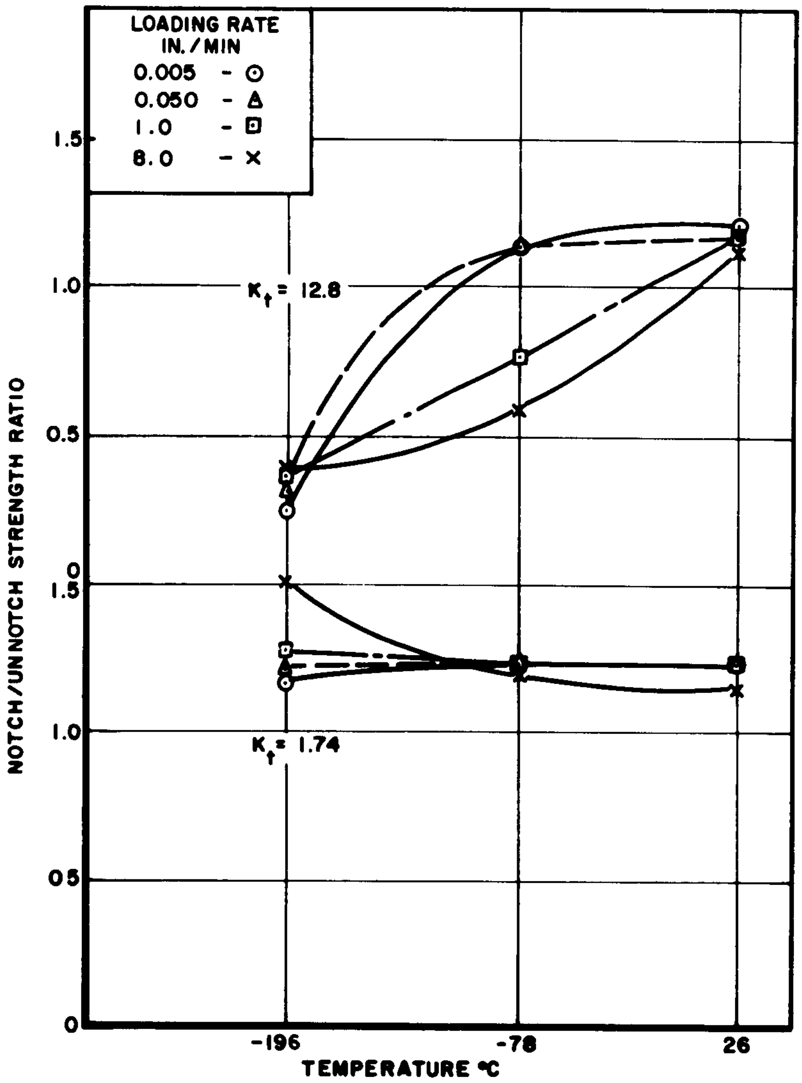


Figure 21. Notch to Unnotch Strength Ratio versus Temperature for Vasco Jet-1000 at Loading Rates of 0.005, 0.050, 1.0, and 8 inches/minute with K_t of 1.74 and 12.8.

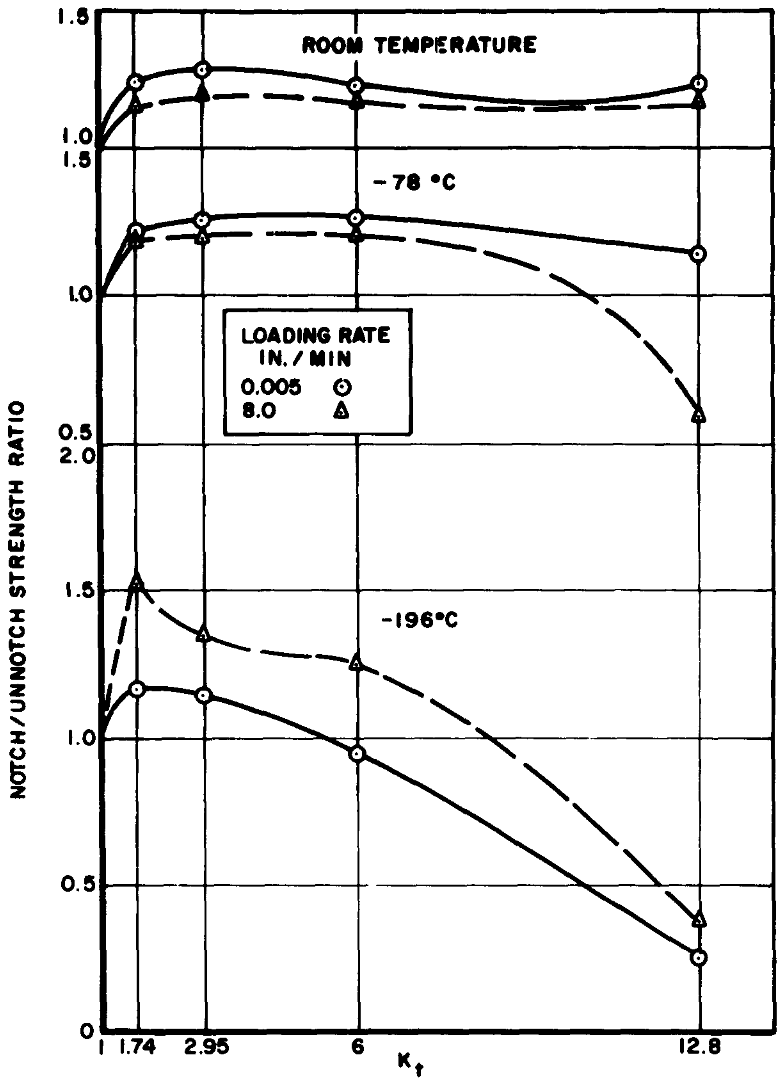


Figure 22. Notch to Unnotch Strength Ratio versus K_t for Vasco Jet-1000 at Loading Rates of 0.005 and 8 inches/minute and Room Temperature, -78°, and -196°C.

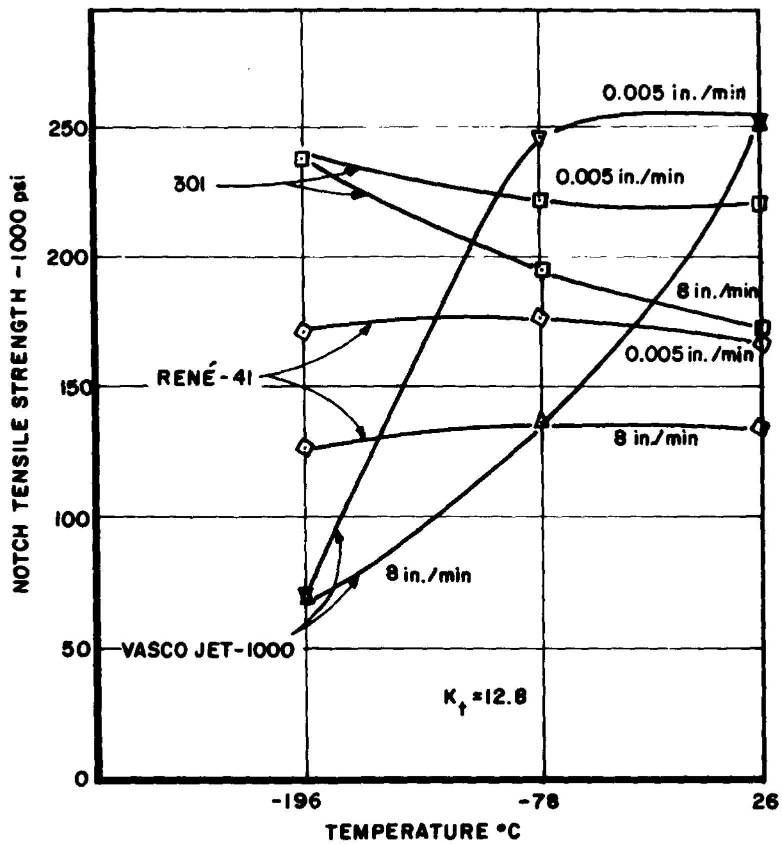


Figure 23. Notch Tensile Strength versus Temperature for 301XH Stainless Steel, René-41, and Vasco Jet-Alloys for K_t of 12.8 and Loading Rates of 0.005 and 8 inches/minute.

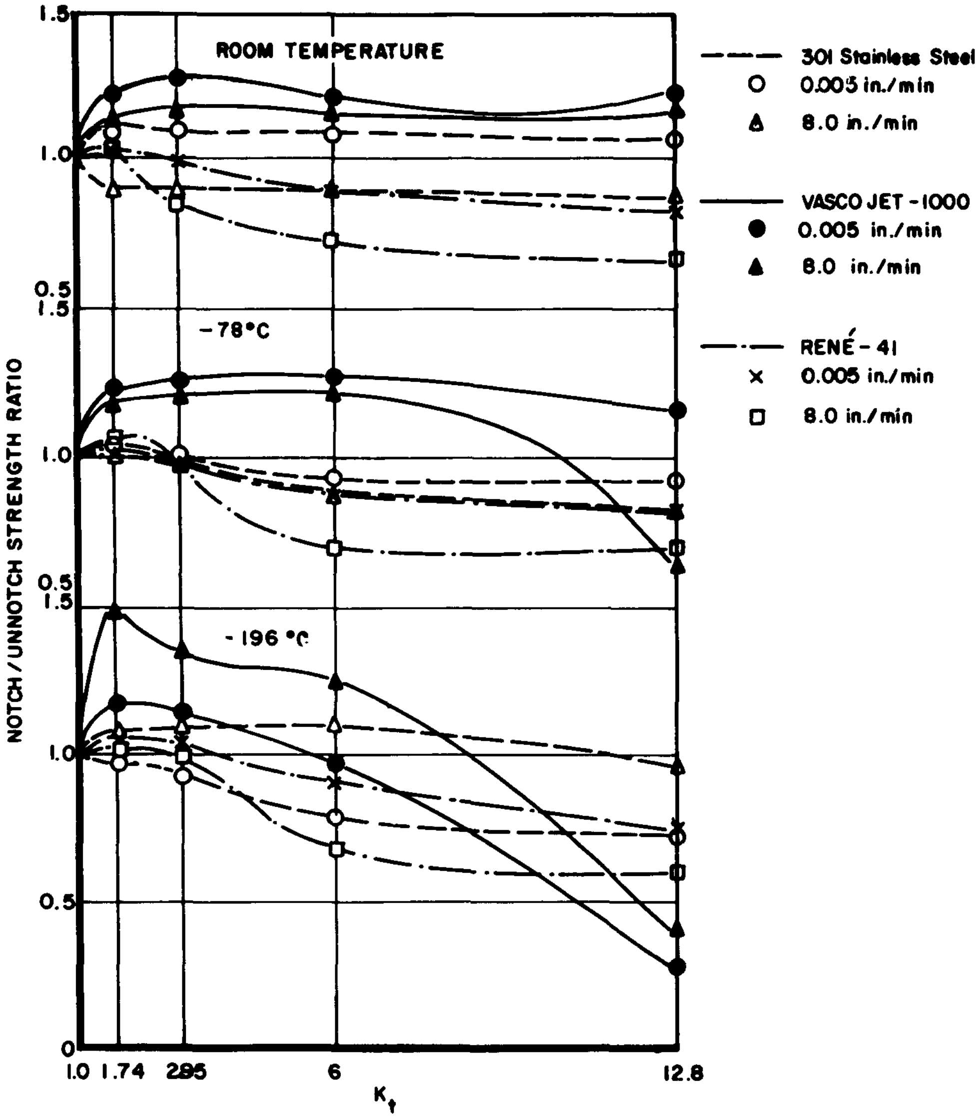


Figure 24. Notch to Unnotch Strength Ratio versus K_t for 301XH Stainless Steel, René-41, and Vasco Jet-1000 Alloys at Room Temperature, -78° and -196°C and at Loading Rates of 0.005 and 8 inches/minute.

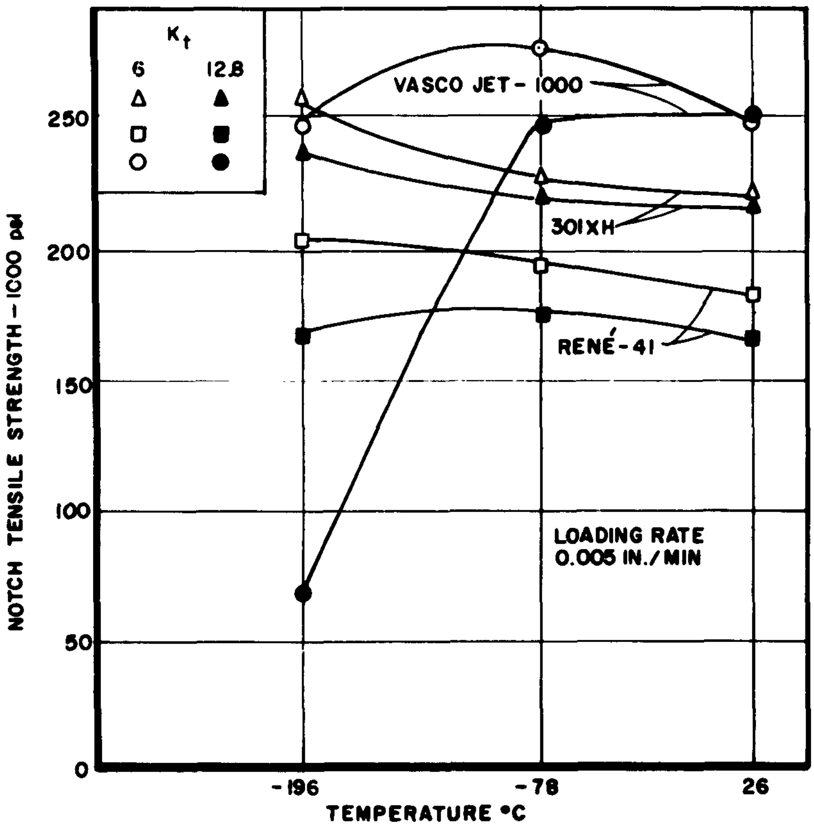


Figure 25. Notch Tensile Strength versus Temperature for 301XH Stainless Steel, René 41, and Vasco Jet-1000 Alloys for K_t of 6.0 and 12.8 at a Loading Rate of 0.005 inch/minute.

Aeronautical Systems Division, Dir/Materials and Processes, Metals and Ceramics Lab, Wright-Patterson AFB, Ohio.
Rpt No. ASD-TDR-62-930. THE INVESTIGATION OF THE EFFECTS OF LOADING RATE AND STRESS CONCENTRATION FACTORS ON THE NOTCH PROPERTIES OF THREE SHEET ALLOYS AT SUBZERO TEMPERATURES. Final report, Mar. 63, pp. incl illus., tables, 13 refs.

Unclassified Report

The effect of theoretical stress concentration factors and loading rates at 26°, -78°, and -196°C are presented for 301XH stainless steel, Rene-41, and Vasco Jet-1000 sheet materials.
The unnotched specimens, tested at room temperature, were not appreciably affected by

(over)

1. Low temperature research
2. Notch properties
I. AFSC Project 7351, Task 735106
II. A. W. Brisbane
III. Aval fr OTS
IV. In ASTIA collection

loading rate; however, some effects were observed for the specimens tested at subzero temperatures. The loading rate had some effect on the notched tensile specimens at all test temperatures. The temperature effect was more pronounced on the notched specimen at the fastest loading rate.
In most instances the tensile strength increased as the temperature decreased.
The notch to unnotched strength ratio decreased as the stress concentration factor increased. The 301XH stainless steel was the least notch sensitive.
The amount of martensite transformed in the notched 301XH stainless steel specimens varied with the notch geometry and loading rate, with the exception of the specimen with a K_t of 12.8 at -196°C.

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